ANALYSIS OF PAEDIATRIC CT HEAD RADIATION DOSES AS AN INITIATION TO ESTABLISH LOCAL DIAGNOSTIC REFERENCE LEVELS

RUNNING TITLE: ANALYSIS OF PAEDIATRIC CT HEAD RADIATION DOSES

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Abstract

Background and objectives

Most of the medical imaging modalities are based on use of ionizing radiation. Ionizing radiation carries the risk of tissue damage and radiation induced malignancy. Therefore, medical imaging should be done under optimal conditions. The purpose of this study was to perform an audit on computed tomography (CT) head radiation doses at the Lady Ridgeway Hospital Colombo (LRH), as an initiation to establish local diagnostic reference levels (LDRL) for the radiology department at LRH.

Methodology

Computed Tomography Dose Index (CTDI_i) and Dose Length Product (DLP) are the International Commission on Radiation Protection (ICRP) recommended radiation dose indicators for CT. The study was performed by retrospective analysis of CT head records over a period of 6 weeks. Data was collected according to patient's age, grouped as <1 year, 1–5 years, 5–9 years and > 9 years. Mean and median for CTDI_{vol} and DLP quantities in each age group were calculated. The median values were used to establish LDRL for the facility.

Results

LDRL values for CT head across the age groups are 30 to 57.2 mGy for CTDI_{vol} and 535.5 to 1235 mGy cm for DLP.

Conclusion

LDRL values for CT head in all age groups at LRH are higher than international DRL values. The difference for DLP is higher than CTDI_{vol} indicating higher scan length and/or higher number of multiphasic studies.

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Introduction

Computed tomography (CT) is one of the most important medical imaging modalities. CT delivers a relatively higher ionizing radiation dose compared to most of the other medical imaging modalities. For example, CT head delivers an effective dose of 2 mSv, compared to the effective dose of 0.04 mSv for two views of skull radiographs¹. Therefore, the radiation dose for CT head is about 50 times that of two views of skull radiographs. Further, about half of the collective effective radiation dose from medical exposures is from CT in many countries². CT head is the most common CT examination performed in children and plays a vital role in the diagnosis of many conditions including life-threatening complications in trauma and other acute conditions, such as hydrocephalus needing immediate treatments.

The risk of harmful effects, especially the risk of cancer, due to exposure to ionizing radiation is higher in children compared to adults³. Therefore, special attention should be paid when exposing children for ionizing radiation. System of radiation protection proposed by the International Commission on Radiation Protection (ICRP) provides fundamental guidance for radiation protection all over the world⁴. According to the proposed guidelines, a medical procedure resulting in exposure of a patient to ionizing radiation need to be both justified and optimized. This means the expected benefit of the examination should outweigh the risk of radiation and all the possible measures should be taken to minimise the amount of radiation exposure.

Medical use of ionizing radiation is unique as a dose limit or constraint cannot be applied². The amount of radiation exposure will depend on the medical condition being investigated. An exposure to higher level of radiation may be justified where there is potential for greater clinical outcome. The concept of Diagnostic Reference Level (DRL) introduced by the ICRP is an effective tool that can be utilized for optimization of diagnostic and interventional procedures that causes exposure of patients to ionizing radiation. According to ICRP publication 135, DRL is defined for a type of equipment for typical examinations on groups of patients within an agreed weight range or, in certain specific circumstances, a standard phantom². DRL is derived from an assumed threshold from a distribution of radiation doses of a set of typical examinations, which is usually the median or mean². If local DRL values are higher than reference values, the aim of optimisation is to reduce the radiation dose and if the local DRL value lies below the reference values, the aim of optimisation should be on image quality².

Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP) are the ICRP recommended radiation dose indicators for establishing DRL values for CT². CTDI is the average absorbed dose, along the z-axis, from a series of contiguous irradiations and $CTDI_{vol}$ is the average absorbed radiation dose over the x, y, and z directions at the centre of the scan from a series of axial scans where the scatter tails are negligible⁵. The DLP is the product of $CTDI_{vol}$ multiplied by total scan length and it represents the total energy absorbed (and thus the potential biological effect) attributable to the complete scan acquisition⁵. In modern CT machines these two dose indexes are displayed in the console after the study and can be easily used for audit purposes.

Wide variation of sizes of paediatric population makes establishing DRL values for children, a more challenging task when compared to adults. For an example, an obese child can be having a weight 100 times that of a premature infant². Therefore, ICRP recommends grouping of paediatric studies according to the patient's age or weight for DRL.

The purpose of this study was to examine radiation dose indicators and exposure parameters for CT head at The Lady Ridgeway Hospital Colombo (LRH), in order to establish LDRL values for CT brain studies for the radiology department at LRH and compare with national and international DRL values, as an initiation for quality assurance.

Materials and methods

Data collection

Ethical approval for the study was granted by the institutional ethical review committee. CT records of the Toshiba Aquilion Prime 160 slice CT scanner were retrospectively analyzed from 24th of October to 30th of November 2017. Data was collected according to age groups of CT protocols and age groups are: <1 years, 1–3 years, 3–5 years, 5–9 years and > 9 years. Later 1 – 3 years and 3 – 5 years age groups were added together to create an age group 1 – 5 years for the purpose of comparison with published data. ICRP recommends to include at least 20 patients for each age category to establish DRL values². Therefore, 20 studies from each age category were included in the study. For each study, patient demographic information, CTDI_{vol} for each phase and DLP for entire study were collected and entered into standard excel sheet.

Statistical analysis and presentation of results

Mean and median for CTDI_{vol} and DLP in each age group were calculated. According to the ICRP recommendations median value is preferred over the mean for establishing DRL for a facility due to the fact that, the median corresponds to the middle of the data distribution². Therefore, the median values were used to establish LDRL for the facility. Since there were no published national DRL values, our LDRL values were compared with published international DRL values.

Results

Information from 100 patients, with 20 patients in each age group were included in this study. The table 1 presents the mean values of CTDI_{vol} and DLP for the <1 year, 1–3 years, 3–5 years, 5–9 years and above 9 years age groups.

The median values of CTDI_{vol} and DLP for each age group is presented on table 2.

Assuming the median values as typical examinations, LDRL values for our institution are presented on table 3. In this table 1 – 3 years and 3 – 5 years age groups are taken under a single age group, 1 – 5 years for the purpose of comparison with international studies.

Figure 1 and figure 2 compare the LDRL values of our institution with the international DRL values from a multinational study⁶, Thailand⁷, India⁸ and Japan⁹.

Our values are higher than almost all the international DRL values except for CTDI_{vol} values for above 9 years age group in Thailand⁷. Compared to the multinational study presented on an article by International Atomic Energy Agency (IAEA) titled, “a study to establish international diagnostic reference levels for paediatric computed tomography”⁶, our LDRL values for CTDI_{vol} are higher by 5.5 % to 33 % with the largest difference seen in the age 5 – 9 years age group. Compared to the same study our LDRL values for DLP are higher by 21.7% to 82.2 %, with the largest difference seen at 1 – 5 years age group.

Discussion

Medical imaging has significantly advanced in the recent years and in fact modern western medicine is heavily dependent on imaging. Harmful effects of ionizing radiation are the main concern over the imaging modalities that involve exposure of patients to ionizing radiation. Therefore, optimization of exposure to ionizing radiation while maintaining satisfactory image quality should be the aim of all the medical imaging departments.

Establishment of local diagnostic reference level (LDRL) quantities for diagnostic procedures for a specific machine or for an imaging department or other facility should be the first step of institutional quality assurance programme². Further, once established, LDRL values can be used for future reference when new equipment and techniques are introduced for the use of same procedure¹⁰. It is well accepted that the presence of institutional and national DRLs help to reduce radiation dose and optimize image quality over the time. In Sri Lanka there is no well-established medical physics support or a system for quality assurance in medical imaging. We have tried to put an initiation for the process of quality assurance at our radiology department from this study.

In the absence of national DRL values for CT head in children we have compared our LDRL values with international DRLs. Our LDRL values lie well above most of the established international DRLs for CT head in children. When compared with the multinational study done in 2015⁶, our LDRLs for CTDI_{vol} are higher by 5.5 % to 33 % and our LDRLs for DLP are higher by 21.7% to 82.2 %. Much significant deference for DLP than CTDI_{vol} indicates higher scan length and/or higher number of multiphasic studies in our practice. Similar results are seen when compared with the DRLs of other countries such as Thailand, India and Japan^{7,8,9}.

In the absence of the support of medical physicists, the results can be worse in other institutions in the country. Further, the availability of alternative imaging modalities such as magnetic resonance imaging (MRI) is limited for children in the country. Therefore, it is likely that the proportion of our children getting exposed to ionizing radiation from CT is higher than the countries with better medical imaging facilities.

This study highlights the need for a survey of CT radiation doses in children at institutional level all over the country and establishment of national DRL values.

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Table 1**Mean values of CTDI_{vol} and DLP according to the age group**

Age group	CTDI _{vol} (mGy)	DLP (mGy cm)
0 – 1 y	30	706.8
1 – 3 y	30	838.4
3 – 5 y	45.8	1357.2
5 – 9 y	57.2	1431
Above 9 y	57.2	1554.1

Table 2**Median values of CTDI_{vol} and DLP according to the age group**

Age group	CTDI _{vol} (mGy)	DLP (mGy cm)
0 – 1 y	30	535.5
1 – 3 y	30	603
3 – 5 y	45.8	1581
5 – 9 y	57.2	1061
Above 9 y	57.2	1235

Table 3**LDRL for CT head at The Lady Ridgeway Hospital for Children**

Age group	LDRL CTDI _{vol} (mGy)	LDRL DLP (mGy cm)
0 – 1 y	30	535.5
1 – 5 y	37.9	984
5 – 9 y	57.2	1061
Above 9 y	57.2	1235